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The presence of a target support structure introduces errors in outdoor RCS measurements. A simple, two scatterer model is used to examine these errors in terms of their effect on target threat predictions.

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RATSCAT

RADAR BACKSCATTER DIVISION
6585th TEST GROUP

PYLON BACKGROUND MEASUREMENT ERROR

TECHNICAL MEMORANDUM

July 3, 1991

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"When the learned man errs, he errs with a learned error."
- Arabic Proverb

Introduction

All radar cross section (RCS) measurements performed on an outdoor range contain some error due to the presence of a target support structure. This structure, typically a low observable pylon or foam column, introduces additional scattered energy not present in a free space measurement. Common practice dictates a 20 dB separation between the target and pylon RCS for a ±1 dB measurement error bound. This separation is not always possible. The objective of this memo is to examine the effect of a smaller target/pylon separation on the measurement error.

Theory

Currie, in his book Radar Reflectivity Measurement: Techniques and Applications (pp. 315, 316), develops an expression for the maximum measurement error caused by the presence of the pylon. His approach is based on the premise that the target and pylon are two independent scatterers. The maximum error occurs when the pylon RCS adds either constructively or destructively to the target RCS. With the addition of a phase term, Currie's formula can be used to calculate the error as a function of the phase difference between the pylon and target. This formulation provides insight on the behavior of the error between the error bounds.

The measurement error is defined as the ratio of the measured target RCS and the actual target RCS. Since RCS is a power measurement, the measured RCS can be expressed in terms of the coherent sum of the target and pylon scattered fields

$$\begin{aligned} T_m &= (\sqrt{T}+\sqrt{P}e^{i\theta})^2 \\ &= T(1+\sqrt{\tfrac{P}{T}}e^{i\theta})^2 \\ &= T\varepsilon \\ \therefore \quad \varepsilon &= \frac{T_m}{T} = (1+\sqrt{\tfrac{P}{T}}e^{i\theta})^2 \end{aligned}$$

where: T_m = measured RCS
T = target RCS
P = pylon RCS
θ = phase difference between T and P
ϵ = measurement error.

The error extremes occur when the phase difference is 0° and 180°. Figure 1 is a typical representation of these error bounds

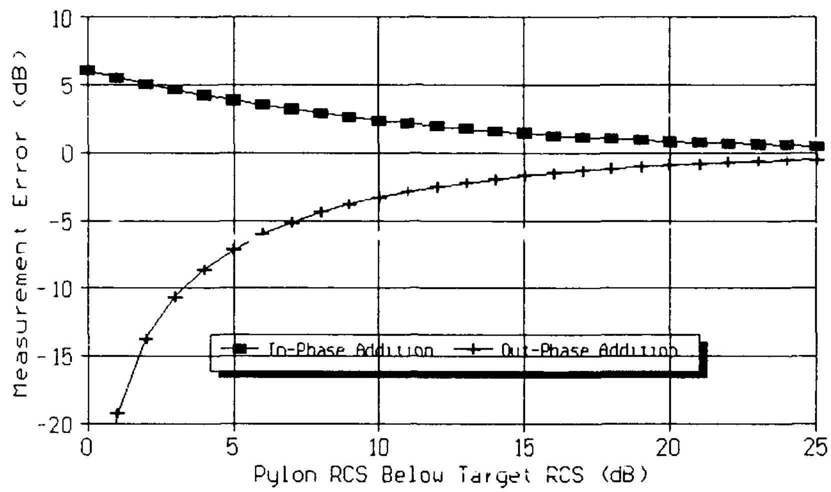

Figure 1 Maximum Measurement Error Due to Backgrounds.

generated by plotting ϵ as a function of the pylon to target RCS ratio. As the pylon RCS gets smaller relative to the target RCS, the error bounds approach zero. Significantly, as the pylon RCS approaches the target RCS the error bounds increase, but with different magnitudes. To better illustrate the implication of this behavior, a specific example is presented.

Example

A target with a -29 dBsm RCS is measured on a -30 dBsm pylon, giving a -1 dB pylon to target RCS ratio. Assuming the pylon is the most significant noise source in the measurement, the measurement error can be tracked as the phase between the pylon and the target RCS varies from 0° to 180°. Figure 2 depicts the measurement error for just such a case. When θ is between 0° and 90°, the pylon RCS adds to the actual target RCS. When θ is between 90° and 180°, the pylon RCS subtracts from the actual target RCS. The error magnitude to the left of 90° is much smaller than the error magnitude to the right. Since the pylon RCS adds or subtracts from the target with equal probability, the measured data will tend to have a much greater error on the small side. This has implications when using the measured RCS to predict target vulnerability. Specifically, given the equal probability of the measurement error adding or subtracting, the threat assessments may turn out overly optimistic.

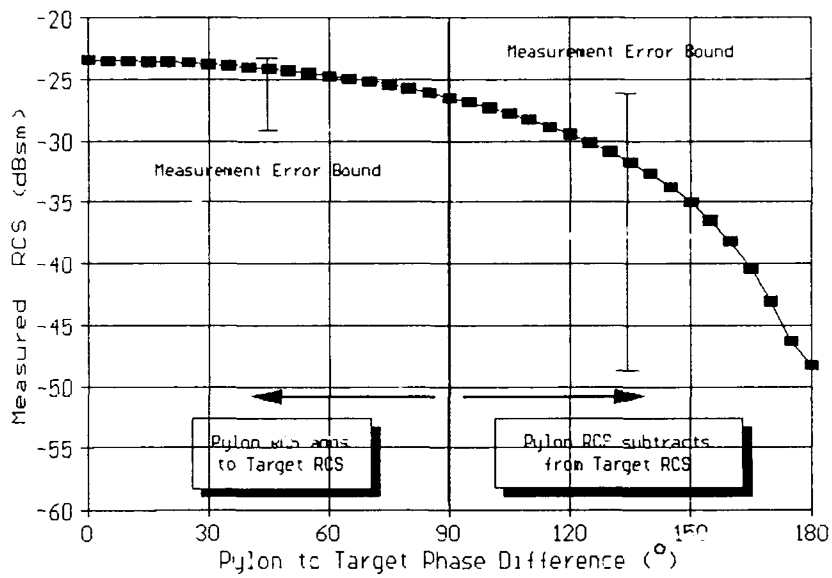

Figure 2 Measurement Error as the Pylon RCS Changes from Adding In-Phase to Adding Out-of-Phase.

Conclusion

The previous analysis assumes the pylon is the most significant source of background error in an outdoor RCS measurement. Further, it acts as a scatterer independent to the target's scattered field. Based on these assumptions, it has been shown that as the pylon to target RCS ratio gets smaller, the RCS that may add to the target is less than the RCS that may subtract from the target. Therefore, threat predictions based on RCS data where there is not adequate target to pylon separation may indicate smaller detection ranges than actually exist.